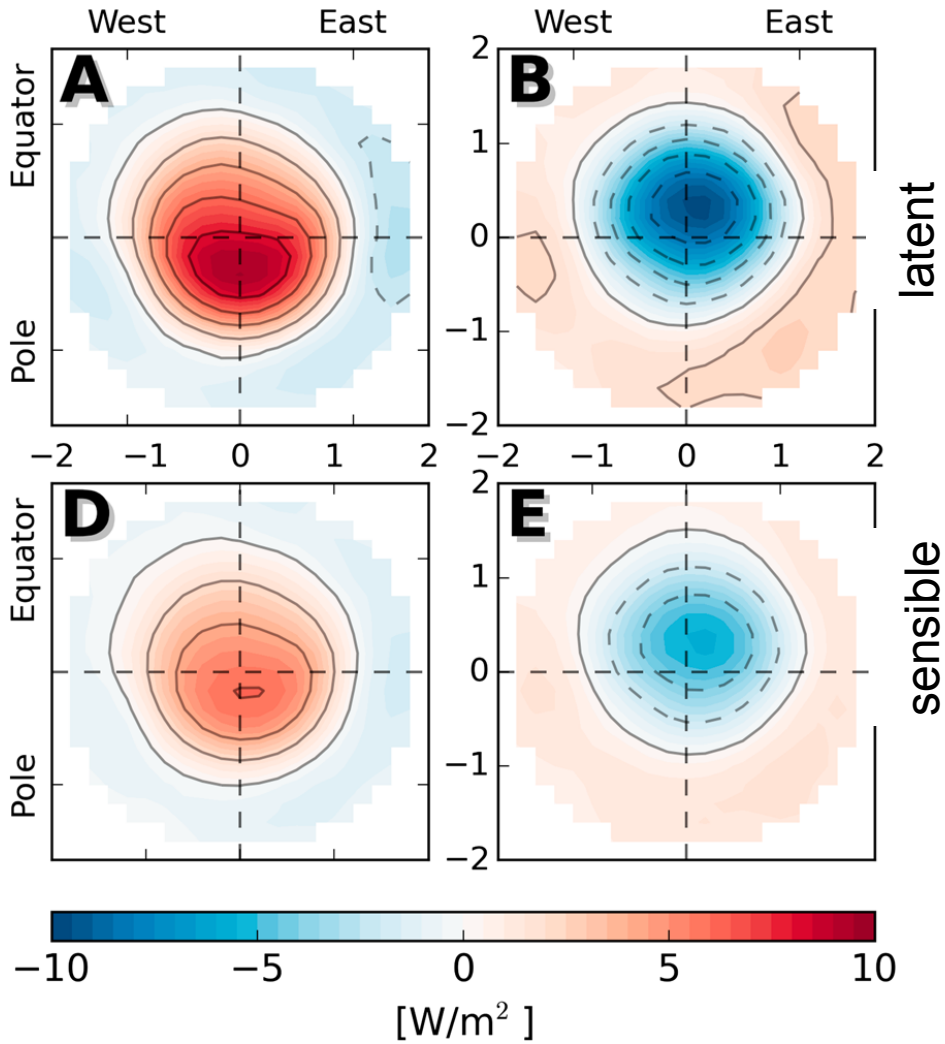
High Resolution Sea Ice Prediction: Coupled Processes and Prediction System Development

Patrick Hogan, Joe Metzger, Jim Richman, Alan Wallcraft, Luis Zamudio, Jay Shriver, Debbie Franklin, Pam Posey, others, NRL-MRY

Naval Research Laboratory
Stennis Space Center, MS USA

High Resolution Workshop
College Park, MD
29 September 2015

Eddies are heat sources/sinks – They need to be resolved.



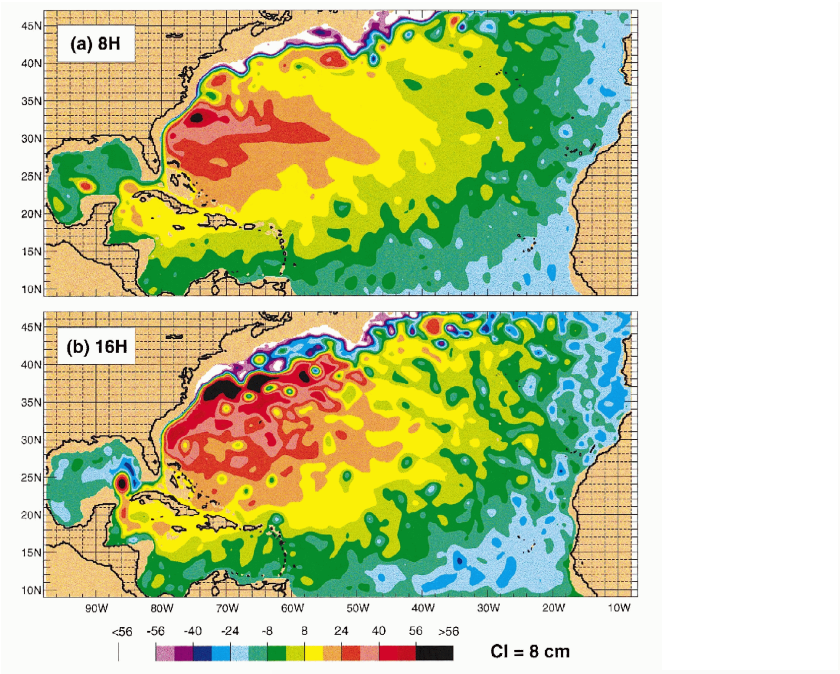
Average composite of latent and sensible heat flux in anticyclonic and cyclonic eddies.

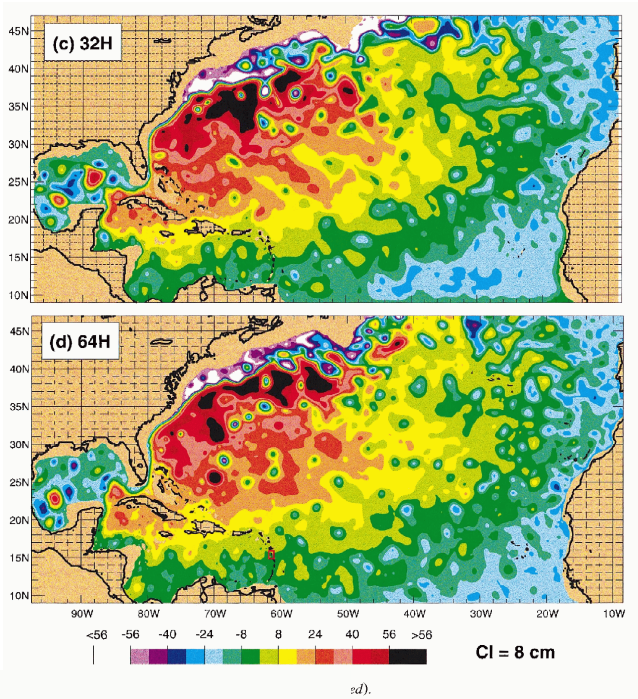
"In strongly energetic regions, eddies explain up to 20% of the total variance in the surface turbulent heat fluxes with averaged anomalies of +/- 10-20 w/m^2."

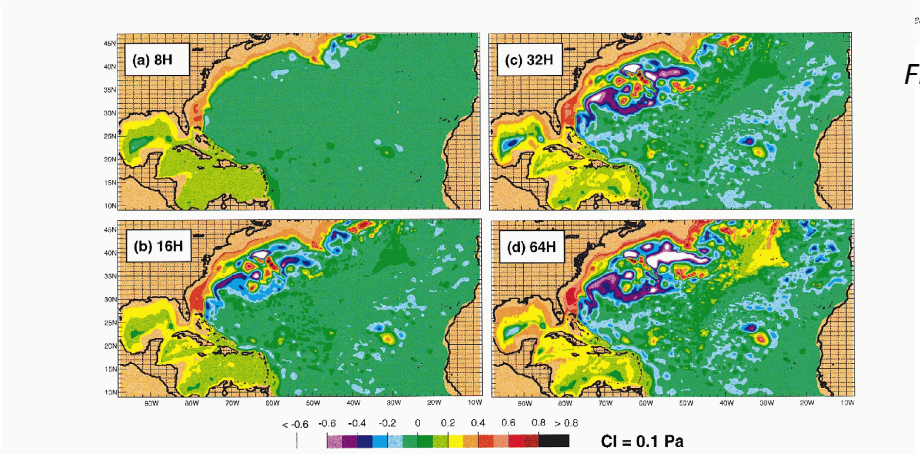
Boas, A.B., O.T. Sato, A. Chaigneau, and G.P. Castelao, (2015), The signature of mesoscale eddies on the air-sea turbulent heat fluxes in the southern Atlantic ocean, 2015, *Geophys. Res. Let.*, 42.

Eddies significantly modify air-sea interaction (both heat and momentum)

Impact of horizontal Grid Resolution on Gulf Stream Separation and Eddy generation, both surface and subsurface





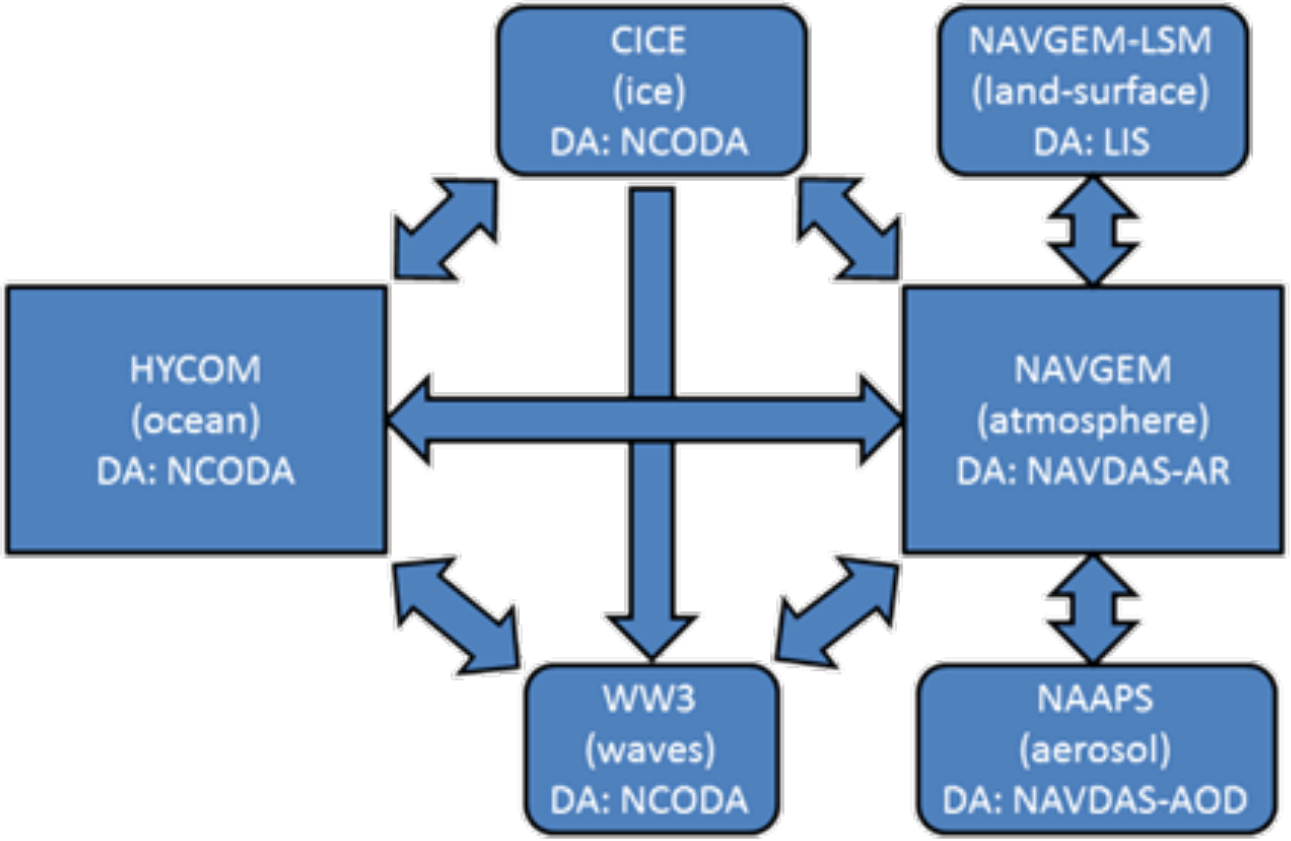


From Hurlburt and Hogan (2008, DAO)

Eddy resolving resolution is necessary both at the surface and at depth

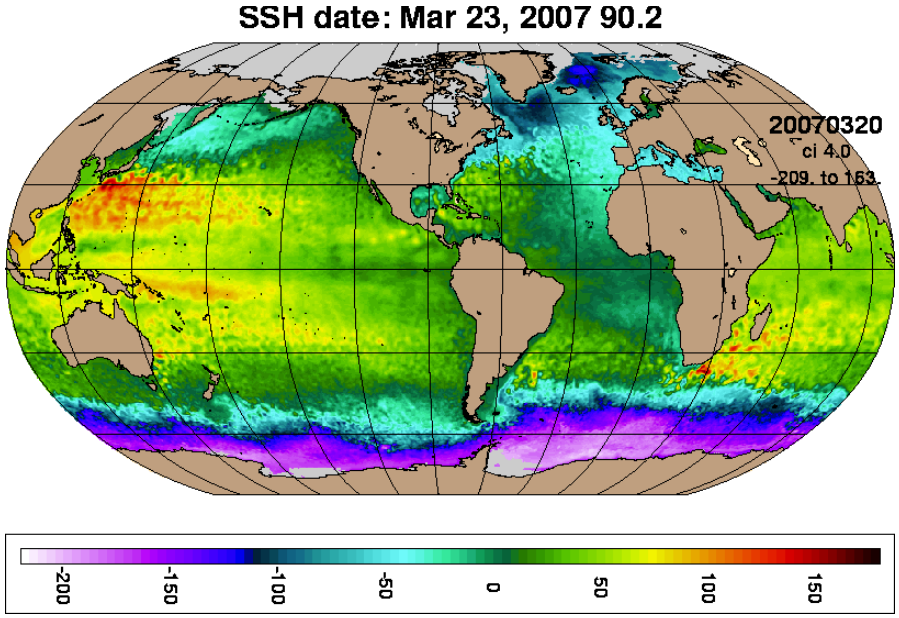
Navy Earth System Prediction Capability (ESPC)
Initial Operational Capability (IOC) 2018

System Components



All components pass through a mediator

Results from Operational GOFS 3.0 (1/12° HYCOM with NCODA Data Assimilation)



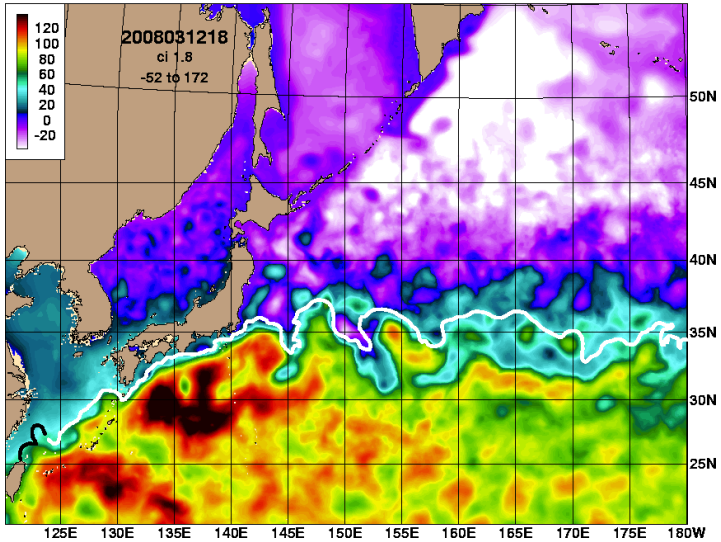
Global SSH on 23 Mar 2007

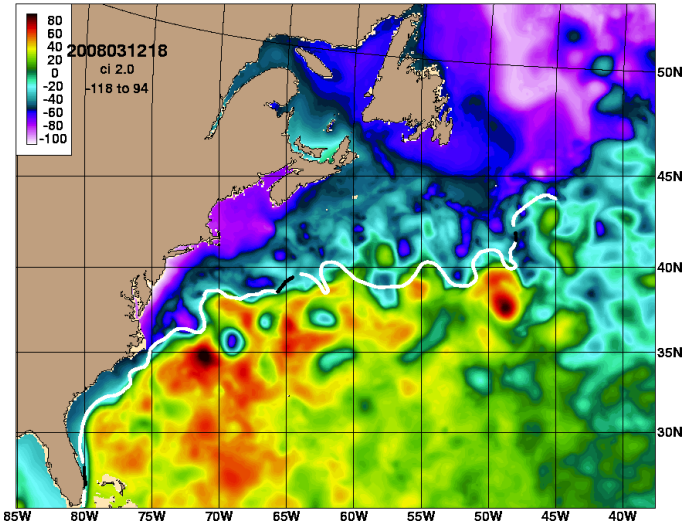
Gray areas are ice covered

- **Horizontal grid: 1/12° equatorial resolution**
  - **4500 x 3298 grid points, ~6.5 km spacing on average, ~3.5 km at pole**
- **Vertical coordinate surfaces: 32 for σ_2***
- **KPP mixed layer model**
- **Thermodynamic (energy loan) sea-ice model**
- **Surface forcing: FNMOC NAVGEM 1.2**
- **Monthly river runoff (986 rivers)**

GOFS 3.1 to be operational Oct. 2015

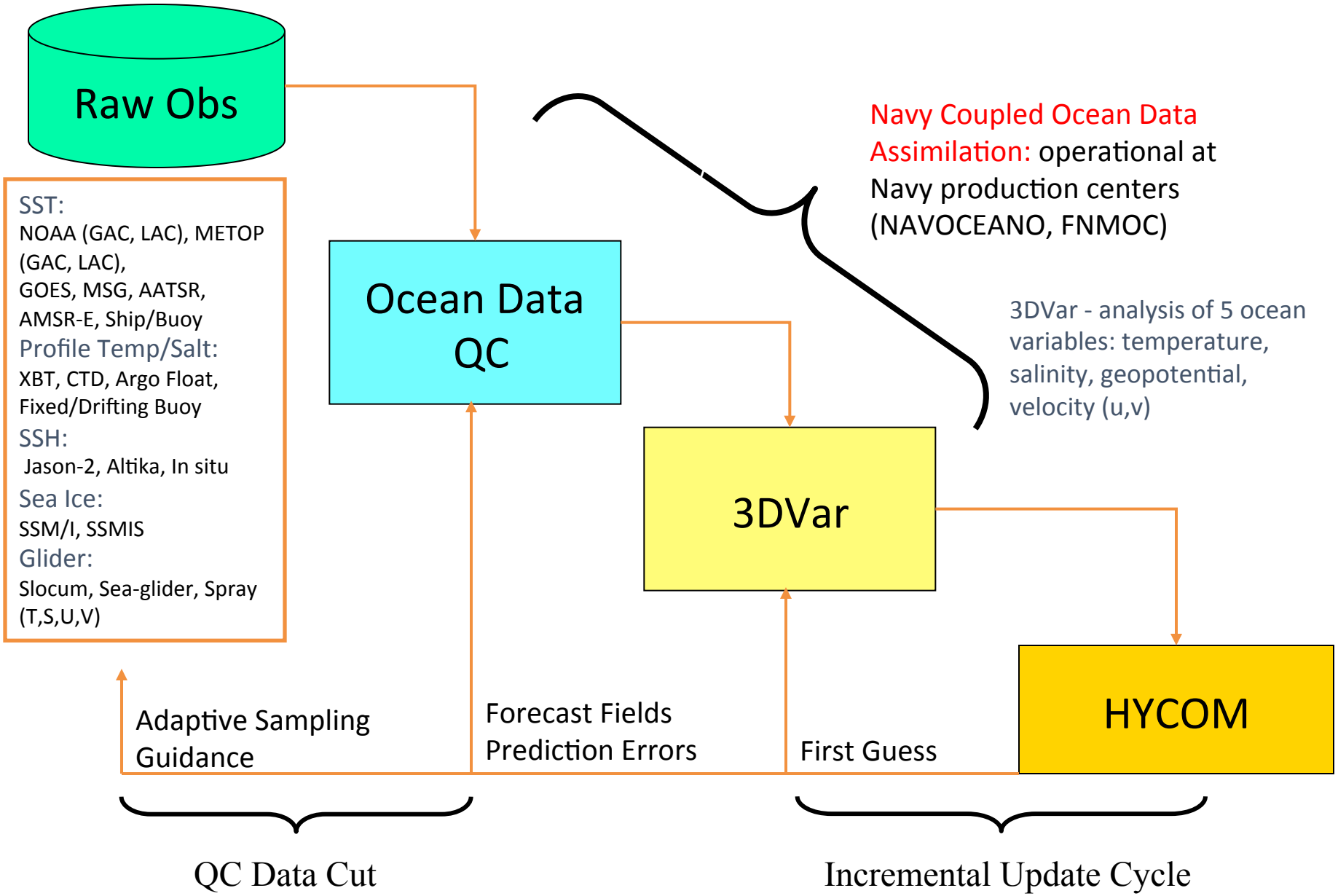
SSH and independent IR frontal analysis: 10 March 2008





Frontal analysis < 4 days old = white, analysis ≥ 4 days old = black

HYCOM Assimilation: NCODA



Navy ESPC
Initial Operational Capability 2018

- Not yet fully defined: initial working definition is NavESPC should be running in pre-operational mode at Navy DSRC under EOM with FNMOC-NAVO-DSRC cycling (uncoupled) DA and producing "prototype products".

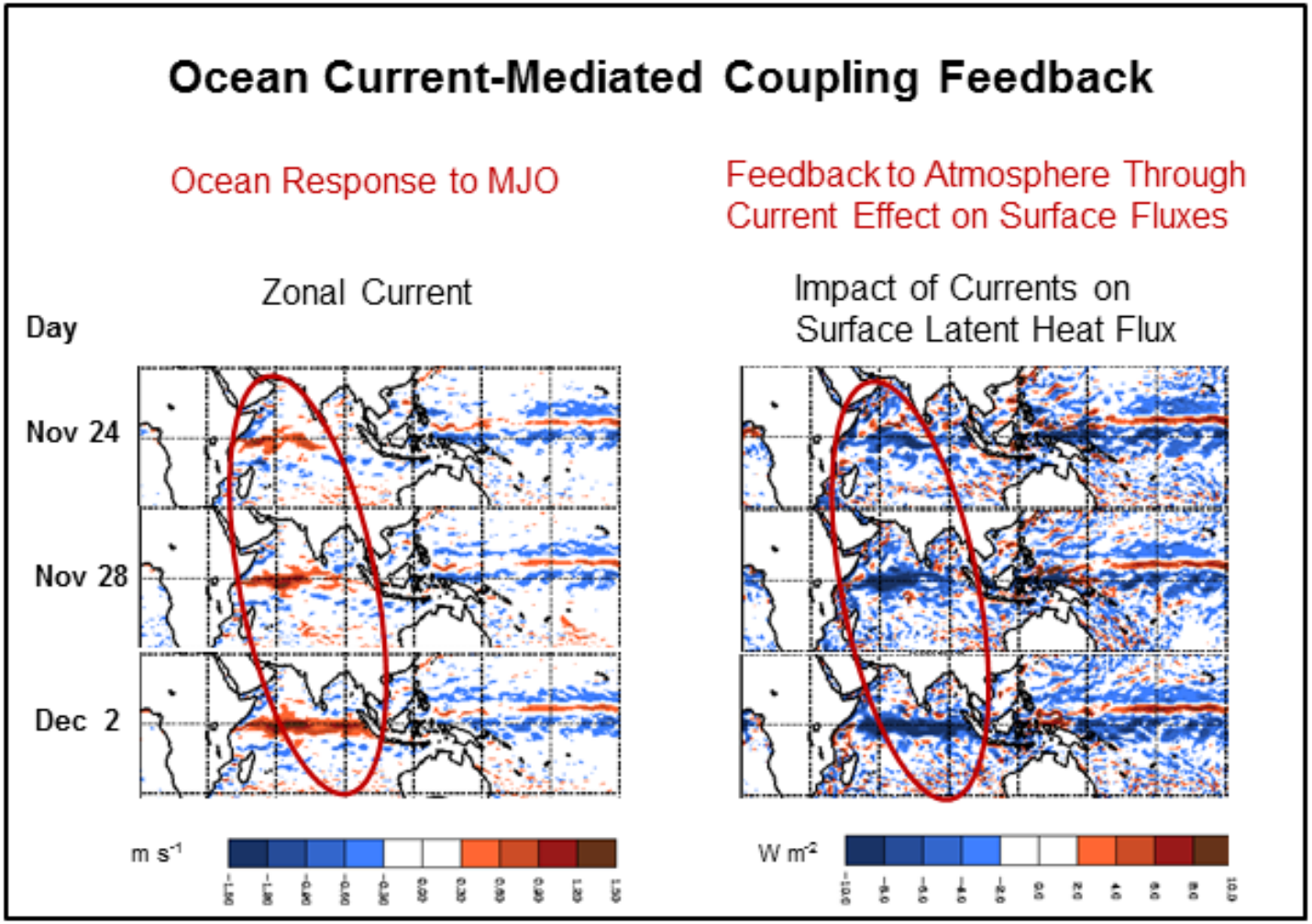
Forecast	Time Scale, Frequency	Atmosphere NAVGEM	Ocean HYCOM	Ice CICE	Waves WW3	Land-Surface NAVGEM-LSM	Aerosol NAAPS
Deterministic short term	0-16 days, Daily	T681 (13 km) 100 levels	1/25° (4.5 km) 41+ layers[1]	1/25° (4.5 km)	1/8° (14 km)	Module within NAVGEM	Module within NAVGEM
Seasonal Ensemble	0-90 days, Weekly 28 members[2]	T681 (19 km) 80 levels	1/12° (9 km) 41 layers	1/12° (9 km)	1/4° (28 km)	Module within NAVGEM	Module within NAVGEM

DRAFT

[1]Vertical resolution of HYCOM still to be determined.

[2]Because the operational centers don't get significantly more time on any one specific day of the week, the ensembles need to be broken up across the week. Run four ensemble members each day of the week.

Impact of ocean current on surface latent heat content

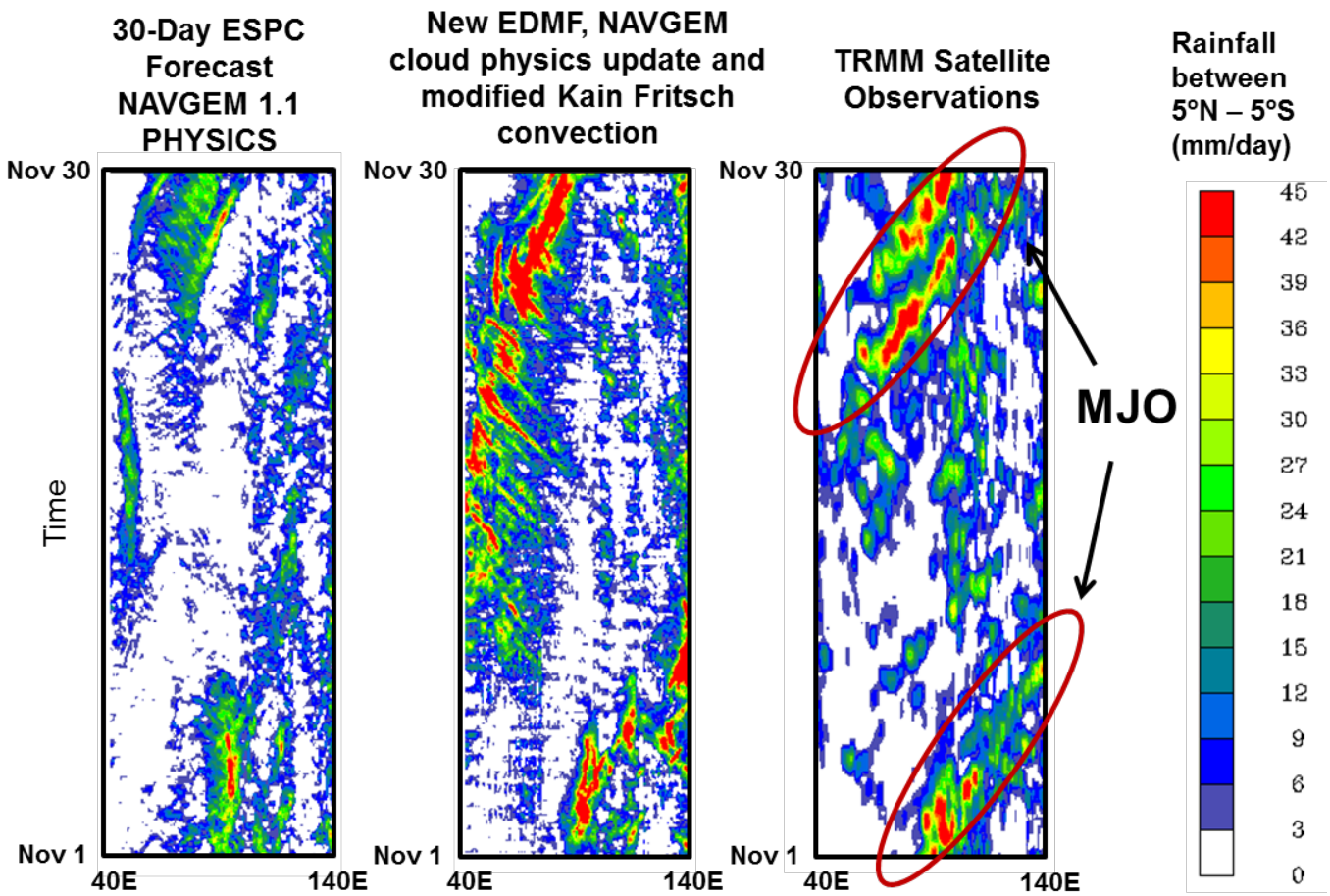


Increased surface stress associated with westerly wind bursts acts to boost the IEC, which in turn impacts air-sea fluxes in HYCOM (left). Feedbacks are nonnegligible, with surface latent heat flux perturbations of up to 10 W/m^2 (right).

NAVGEM-HYCOM-CICE Coupling

30-day integrations from 1 Nov 2011

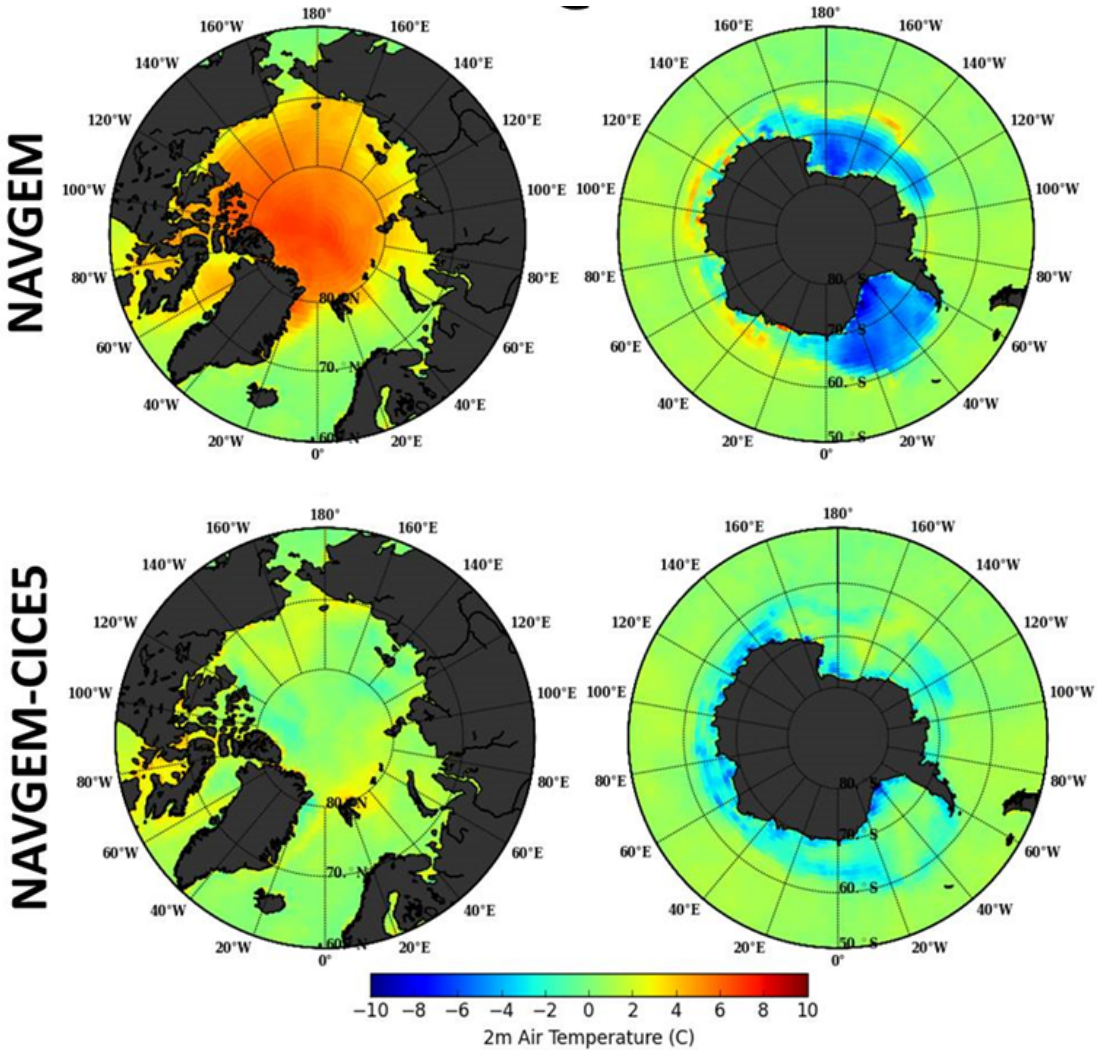
The sensitivity of MJO predictive skill in the coupled system to modifications of the NAVGEM physics as compared to air-sea interaction is a topic of ongoing research.



Jim Ridout, NRL-MRY

Impact of Coupled ocean-Ice-Atmosphere in Polar Regions

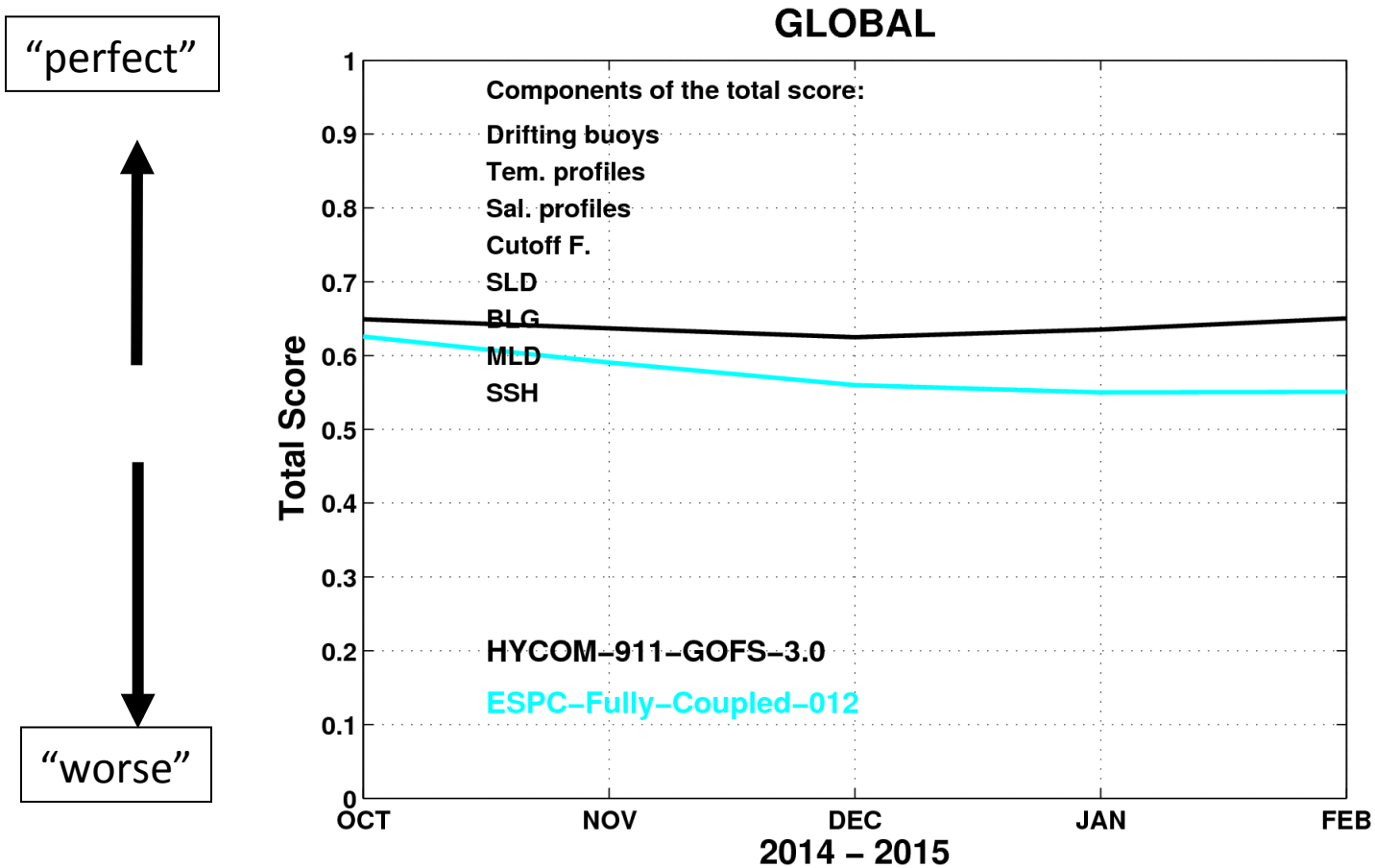
2 m air temperature bias of 120 hour forecasts for May 2014



Coupled system has significantly less bias

Ocean Model Scorecard Example

ESPC Forecast vs. GOFS Operational Analysis



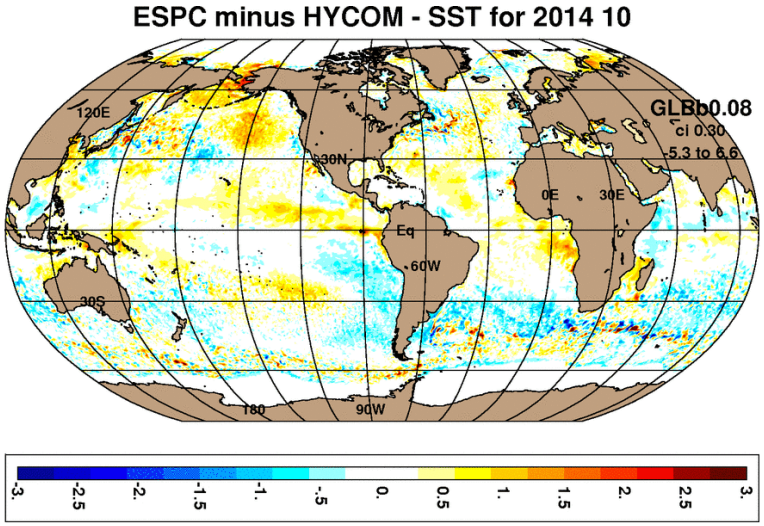
Score_model(i) = 1 – (Error_model(i) / Maximum_error(i))

Total_score_model = mean (Score_model(i))

Luis Zamudio, NRL-SSC

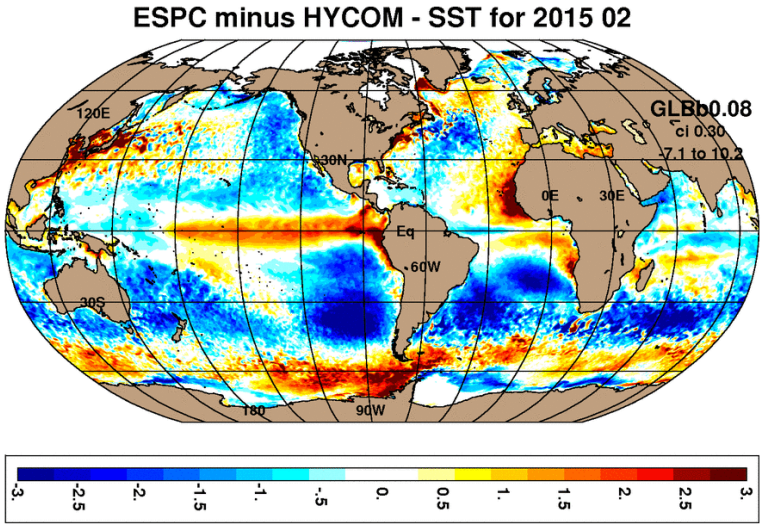
ESPC Forecast SST vs. Operational SST Analysis

Coupled (ESPC) monthly mean forecast vs.
non-coupled (GOFS) monthly mean analysis



Difference after 1-month forecast

Warm bias (false El Nino)



Difference after 5-month forecast

Preliminary Results from 180 day Coupled Simulation

- The Navy ESPC coupled system has been run for 180 days starting from uncoupled initial states on 31 March 2014
- Coupled model develops a strong El Nino (warm bias) when no El Nino occurred
  - Most forecasts that year developed an El Nino
  - May have a warm bias in ocean IC
  - NAVGEM winds may be too weak
  - Land biases reflect analyses performed at 0000Z
- Still have problems with
  - Double ITCZ
  - Tropical cyclogenesis
  - Rainfall over Indonesian
- Improvements
  - Asian Monsoon

Navy ESPC
Initial Operational Capability 2018

- Not yet fully defined: initial working definition is NavESPC should be running in pre-operational mode at Navy DSRC under EOM with FNMOC-NAVO-DSRC cycling (uncoupled) DA and producing "prototype products".

Forecast	Time Scale, Frequency	Atmosphere NAVGEM	Ocean HYCOM	Ice CICE	Waves WW3	Land-Surface NAVGEM-LSM	Aerosol NAAPS
Deterministic short term	0-16 days, Daily	T681 (13 km) 100 levels	1/25° (4.5 km) 41+ layers[1]	1/25° (4.5 km)	1/8° (14 km)	Module within NAVGEM	Module within NAVGEM
Seasonal Ensemble	0-90 days, Weekly 28 members[2]	T681 (19 km) 80 levels	1/12° (9 km) 41 layers	1/12° (9 km)	1/4° (28 km)	Module within NAVGEM	Module within NAVGEM

DRAFT

[1]Vertical resolution of HYCOM still to be determined.

[2]Because the operational centers don't get significantly more time on any one specific day of the week, the ensembles need to be broken up across the week. Run four ensemble members each day of the week.

- Deterministic: ~ 6 hours on ~9000 cores
- Seasonal Ensemble ~18 hours on ~2200 cores
- So, ~9000 cores ~24 hrs/day likely enough for both (6 hrs for deterministic, 18 hrs for 4x ens)